

## Chemical Bonding and Reactions

**PS-4 The student will demonstrate an understanding of chemical reactions and the classifications, structures, and properties of chemical compounds.**

### **PS-4.1 Explain the role of bonding in achieving chemical stability.**

**Taxonomy Level:** 2.7-B Understand Conceptual Knowledge

#### **Key Concepts:**

Stability: Noble gas configuration

Bond: Ionic bond, Covalent bond

Ion

**Previous/Future knowledge:** In the 7<sup>th</sup> grade students recognize that matter is composed of extremely small particles called atoms (7.1); classify matter as element, compound, or mixture on the basis of its composition (7.2); compare the physical properties of metals and nonmetals (7.3); and use the periodic table to identify the basic organization of elements and groups of elements (including metals, nonmetals, and families) (7.2).

In Physical Science students will expand their concepts of atoms and how they bond with other atoms to form compounds. A key concept will be the formation of chemical bonds to make the atoms more stable.

#### **It is essential for students to**

- Understand that all of the noble gases are chemically stable. This is the observable fact that is the basis for all theories dealing with bonding.
- Understand that a *noble gas electron configuration* (an outside energy level with 2 or 8 electrons) is chemically *stable* and that all atoms would be more stable if they had these electron configurations. When forming compounds, atoms gain, lose, or share electrons to reach an electron situation equal or similar to one of the noble gases.
  - Helium atoms are stable atoms with **two** electrons in the outside energy level. Some atoms will lose, gain, or share electrons to have two electrons like helium and become chemically stable.
  - Atoms of the other noble gases (neon, argon, krypton and radon) are stable atoms with **eight** electrons in the outside energy level. Some atoms lose, gain or share electrons to have **eight** electrons in the outside energy level like the closest noble gas and become chemically stable.
- Understand that when atoms bond chemically, they do so to become more stable.
  - Having the outside energy level full or “complete” like noble gases is more stable than other electron arrangements.
  - To achieve stability metals may lose electrons and nonmetals may gain electrons producing *ions* which form *ionic bonds*.
    - Group 1 and Group 2 metals lose electrons so that their outside energy level is “complete” or full, forming a stable electron structure like a noble gas. They become positively charged particles (positive ions) because there are fewer electrons (-) than protons (+).
    - Group 16 and Group 17 nonmetals tend to gain electrons so that their outside energy level is “complete” or full, forming a stable electron structure like a noble gas. They become negatively charged particles (negative ions) because there are more electrons (-) than protons (+). Oppositely charged ions attract each other to form ionic bonds.
  - Nonmetal atoms bond with each other by sharing electrons to obtain an electron situation like one of the noble gases and, therefore, become stable. This type of bonding is called *covalent bonding*.

## Chemical Bonding and Reactions

**PS-4 The student will demonstrate an understanding of chemical reactions and the classifications, structures, and properties of chemical compounds.**

### **It is not essential for students to**

- Understand hybridization of orbitals or exceptions to the octet rule. At this point students only need to know that atoms achieve stability through bonding to achieve a stable configuration with an electron situation like one of the noble gases (two or eight electrons in the outer energy level).

### **Assessment Guidelines:**

The objective of this indicator is to explain the role that bonding has in the achievement of chemical stability, therefore, the primary focus of assessment should be to construct cause and effect models about how elements form bonds to attain stability (an electron situation like one of the noble gases, which have two or eight electrons in the outer energy level).

In addition to explain, assessments may require that students

- Summarize the major points about elements bonding to achieve stability;
- Compare the number of electrons in a stable configuration and a less stable configuration;
- Infer whether bonded or unbonded atoms are more stable; or
- Exemplify elements that transfer electrons or share electrons.

## Chemical Bonding and Reactions

**PS-4 The student will demonstrate an understanding of chemical reactions and the classifications, structures, and properties of chemical compounds.**

**PS-4.2 Explain how the process of covalent bonding provides chemical stability through the sharing of electrons.**

**Taxonomy Level:** 2.7-B Understand Conceptual Knowledge

### Key Concepts:

Covalent bond

Sharing electrons

Electron pair

Molecule

**Previous/Future knowledge:** In the 7<sup>th</sup> grade students were introduced to atoms as summarized in indicator 7-4.1. Students have not been previously introduced to the concepts in this indicator. In Physical Science students will explain the concept of covalent bonding and sharing electrons to become more chemically stable.

### It is essential for students to

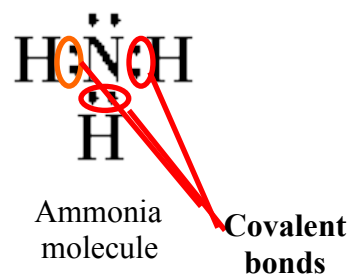
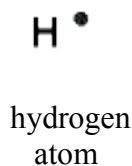
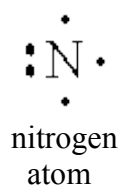
- Understand that nonmetals have less than the number of electrons that they need in order to have a stable outer-shell arrangement. Nonmetals may gain electrons through ionic bonding or share electrons through covalent bonding to become more stable.
  - It is possible for two nonmetal atoms to share electrons in order to become more stable
    - For example: An atom from group 17 can bond with another group 17 atoms by sharing one electron from each atom. Sharing electrons in this manner results in both atoms attaining eight electrons in their outer energy level and each would have a stable number of electrons equal to the nearest noble gas.
    - The atoms would form one covalent bond consisting of two shared electrons.
    - The *molecule* formed is more stable than the individual atoms.
  - In water, oxygen shares two pairs of electrons, one pair with each of two hydrogen atoms, forming one covalent bond with each. This gives the oxygen atom eight outer energy level electrons and each hydrogen atom, two outer energy level electrons. All of the atoms in the molecule are stable since they each have a number of electrons equal to the nearest noble gas.
  - A hydrogen molecule, H<sub>2</sub>, forms a covalent bond by sharing the electron from each hydrogen atom. This gives each hydrogen atom two electrons in the outside energy level which is stable.
- There are many other combinations of nonmetals that achieve electron stability by sharing different numbers of electrons to have a number of electrons like a noble gas (2 or 8 electrons in the outer energy level).
  - Multiple bonds form when more than one pair of electrons is shared. A nitrogen molecule, N<sub>2</sub>, has five electrons and needs to gain three electrons to be stable. This sharing is done when three electrons from each nitrogen atom are shared forming a “triple bond” (three covalent bonds). An oxygen molecule, O<sub>2</sub>, forms a double bond when two electrons from each atom are shared.
  - A carbon dioxide molecule, CO<sub>2</sub>, forms when carbon, which needs four electrons to be stable, shares two electrons from each oxygen atom, which needs two electrons to be stable, forming “double bonds” (two covalent bonds) between each oxygen atom and the carbon atom.

## Chemical Bonding and Reactions

**PS-4 The student will demonstrate an understanding of chemical reactions and the classifications, structures, and properties of chemical compounds.**

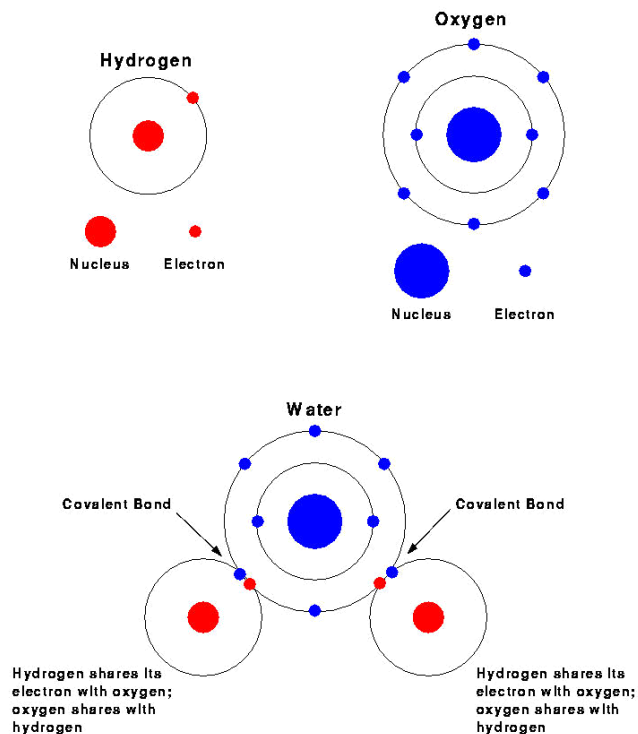
- Show examples of covalent bonding or recognize examples of covalent bonding.
  - Examples may be in the form of “dot” diagrams, pictorial diagrams, or verbal descriptions.
    - Atomic illustrations must indicate which element the illustration represents and the number of electrons in the outer-most energy level of the atom (see PS-2.5).
    - Molecular illustrations must indicate the identity of the elements that compose the molecule and show all atoms sharing electrons in the outer-most energy levels such that each atom in the molecule has a complete outer-most energy level.
    - The shared pairs of electrons in the molecular illustration should be labeled as “covalent bonds”

### Example of Electron Dot Diagrams



### Example of Pictorial Diagrams

#### Covalent Bonds in Water



## Chemical Bonding and Reactions

**PS-4 The student will demonstrate an understanding of chemical reactions and the classifications, structures, and properties of chemical compounds.**

### Example of a Written/Verbal Description

- An atom of hydrogen has one electron in its outer-most energy level. Two electrons are required for hydrogen to have a stable outer-most energy level.
- An atom of chlorine has seven electrons in its outer most-energy level. Eight electrons are required for chlorine to have a stable outer-most energy level.
- A molecule of hydrogen chloride forms when the one electron in the outer-most energy level of a hydrogen atom, and one of the electrons in the outer-most energy level of the chlorine atom are shared.
- The shared electrons occupy both the outer energy level of the chlorine atom and the outer energy level of the hydrogen atom. In the resulting molecule, the hydrogen atom has two electrons in its outer most energy level, (the original hydrogen electron and the electron it is now sharing from the chlorine atom) and the chlorine atom has eight electrons in its outer most energy level, (the original seven chlorine electrons and the electron it is now sharing from the hydrogen atom).
- The sharing of two electrons (one from each atom) is called a covalent bond.

### It is not essential for students to

- Understand double or triple covalent bonds with organic compounds;
- Understand molecular shapes;
- Understand resonance;
- Understand hybridization of orbitals.

### Assessment Guidelines:

The objective of this indicator is to explain how the process of covalent bonding provides chemical stability through the sharing of electrons, therefore, the primary focus of assessment should be to construct a cause and effect model relating covalent bonds to sharing electrons and to achieving stability. Assessments will not only test the student's knowledge that covalent bonds are shared electrons but why they are formed.

In addition to explain, assessments may require that students to

- Compare covalently bonded atoms to unbonded atoms;
- Summarize covalent bonding and stable configurations;
- Infer that particular elements will form covalent bonds;
- Represent covalent bonds in dot diagrams, pictorial diagram or word descriptions;
- Exemplify covalently bonded compounds;
- Classify bonds as covalent or not covalent.

## Chemical Bonding and Reactions

**PS-4 The student will demonstrate an understanding of chemical reactions and the classifications, structures, and properties of chemical compounds.**

**PS-4.3 Illustrate the fact that ions attract ions of opposite charge from all directions and form crystal lattices.**

**Taxonomy Level:** 2.2-B Understand Conceptual Knowledge

### Key Concepts:

Ionic bonds                      Ions  
Electron transfer              Crystal lattice

**Previous/Future knowledge:** In the 7<sup>th</sup> grade students were introduced to atoms as summarized in indicator 7-4.1. Students have not been previously introduced to the concepts in this indicator. In Physical Science students will explain the concept of ionic bonding and transfer of electrons to become more chemically stable. Ions with opposite electrical charges attract and stick together to form a crystal lattice.

### It is essential for students to

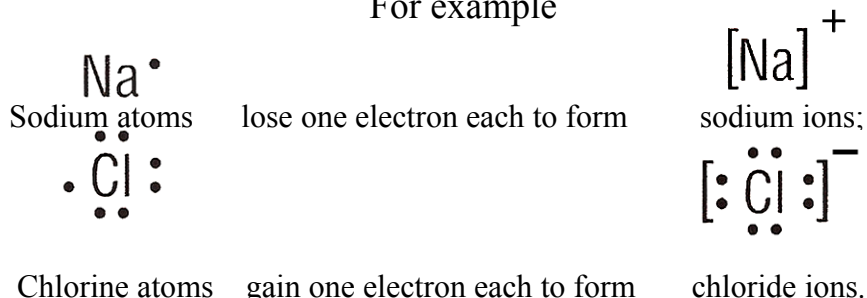
- Understand that metal atoms tend to lose electrons to become stable and that metals in groups 1 and 2 can most easily achieve a stable electron configuration by losing electrons to obtain an electron situation like the closest noble gas. For example:
  - Group 1 metals have one electron in the outer energy level which is one more than the noble gas just before it in the periodic table. Group 1 metals will tend to lose one electron so that its outer energy level becomes stable like the closest noble gas. The atom becomes an ion with a 1+ charge because the number of electrons (-) is now one less than the number of positive protons.
  - Group 2 metals have two electrons in the outer energy level which is two more than the noble gas just before it in the periodic table. Group 2 metals will tend to lose two electrons so that the outer energy level becomes stable like the closest noble gas. The atom becomes an ion with a 2+ charge because the number of electrons (-) is now two less than the number of positive protons.
- Understand that nonmetal atoms tend to gain electrons. For example:
  - Group 16 atoms have two electrons less than the closest noble gas on the periodic table and six electrons in the outside energy level. Group 16 atoms, such as oxygen, become stable by gaining two electrons so that its outer energy level becomes like the closest noble gas. The atom becomes an ion with a 2- charge because it now has two more negative electrons (-) than positive protons.
  - Group 17 atoms have one electron less than the closest noble gas on the periodic table and seven electrons in the outside energy level. Group 17 atoms, such as chlorine, can become stable most easily by gaining one electron so that its outer energy level becomes like the closest noble gas. The atom becomes an ion with a 1- charge because it now has one more negative electron (-) than positive protons.
- Understand that ionic bonds form when positively charged metal ions attract negatively charged nonmetal ions due to the attraction between oppositely charged particles.
  - Positively and negatively charged ions surround each other and pack together as closely as possible to form an ionic crystal.
  - The ions cluster in a ratio that will cancel the net charge of the ions.

## Chemical Bonding and Reactions

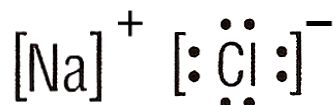
**PS-4 The student will demonstrate an understanding of chemical reactions and the classifications, structures, and properties of chemical compounds.**

- Show examples of ionic crystals or recognize examples of ionic crystals.
  - Examples may be in the form of pictorial diagrams, or verbal descriptions or electron dot formulas.
  - Illustrations of ions should indicate the name and the charge of the ion the illustration represents.
  - Illustrations of crystals must indicate the identity of the ions that compose the crystal and show the ions in a crystal lattice. (PS-2.5)

For example

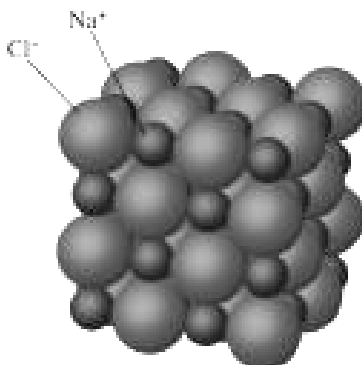


These oppositely charged ions then attract each other in a one to one ratio to form a crystalline arrangement of many ions. Sodium chloride can be represented as follows:



Sodium chloride

or as a Pictorial diagram:



**It is not essential for students to**

- Predict the types of crystals that ions will form;
- Predict or explain ionic bonding for ionic crystals other than those formed by Groups 1,2,16, and 17 elements unless the charge of the ion is given.

## Chemical Bonding and Reactions

**PS-4 The student will demonstrate an understanding of chemical reactions and the classifications, structures, and properties of chemical compounds.**

### Assessment Guidelines:

The objective of this indicator is to *illustrate* that ions attract ions of opposite charge from all directions to form crystal lattices, therefore, the primary focus of assessment should be to use diagrams, pictures, or word models to show that positive and negative ions attract each other to form crystals.-

In addition to illustrate, assessments may require students to

- *Classify* substances as ionic crystals;
- *Summarize* the formation of ionic crystals and ions;
- *Compare* the formation of positive and negative ions;
- *Represent* ionically bonded compounds; or
- *Exemplify* positive and negative ions.

## Chemical Bonding and Reactions

**PS-4 The student will demonstrate an understanding of chemical reactions and the classifications, structures, and properties of chemical compounds.**

**PS-4.4 Classify compounds as crystalline (containing ionic bonds) or molecular (containing covalent bonds) based on whether their outer electrons are transferred or shared**

**Taxonomy Level:** 2.3-B Understand Conceptual Knowledge

### Key Concepts:

Ionic crystals

Molecular substances

**Previous/Future knowledge:** In the 7<sup>th</sup> grade students translated chemical symbols and the chemical formulas of common substances to show the component parts of the substances (including NaCl [table salt], H<sub>2</sub>O [water], C<sub>6</sub>H<sub>12</sub>O<sub>6</sub> [simple sugar], O<sub>2</sub> [oxygen gas], CO<sub>2</sub> [carbon dioxide], and N<sub>2</sub> [nitrogen gas]). (7-5.2)

In Physical Science students will expand their concepts of chemical compounds and elements by classifying the bonds as ionic or covalent and the combination as molecular or crystalline compounds.

### It is essential for students to

#### *Ionic Crystals*

- Understand that ionic crystals consist of metals bonded to nonmetals.
  - In general when metals react with nonmetals, electrons are transferred from the metals to the nonmetals.
  - The metals form positive ions and the nonmetals form negative ions.
  - Positively charged metal ions attract negatively charged nonmetal ions.
  - These positive and negatively charged ions pack together as closely as possible in a crystal lattice to form an ionic crystal.
  - Examples of ionic crystals may include: sodium chloride (NaCl), sodium hydroxide (NaOH), calcium fluoride (CaF<sub>2</sub>), and potassium iodide (KI).

#### *Molecular Substances*

- Understand that molecular substances often consist of nonmetals.
  - When nonmetals form compounds with other nonmetals, they form covalent bonds.
  - Nonmetals will share electrons with each other to become stable.
  - Bonds formed by sharing electrons are covalent bonds.
  - Molecules are compounds that have covalent bonds.
  - Examples of molecular substances may include: hydrogen gas (H<sub>2</sub>), carbon dioxide (CO<sub>2</sub>), water (H<sub>2</sub>O), and sugar (C<sub>6</sub>H<sub>12</sub>O<sub>6</sub>).

### It is not essential for students to

- Classify covalently bonded molecules other than combinations of nonmetals unless they are told that the electrons are shared;
- Understand percent ionic character.

## Chemical Bonding and Reactions

**PS-4 The student will demonstrate an understanding of chemical reactions and the classifications, structures, and properties of chemical compounds.**

### Assessment Guidelines:

The objective of this indicator is to classify compounds as crystalline or molecular based on the bonding, therefore, the primary focus of assessment should be to detect the features of ionic compounds or covalent molecules that would place those substances into a particular group.

In addition to classify, assessments may require that students

- Exemplify an ionic or covalent compound based on the type of bond;
- Compare ionic and covalent bonds, and also molecular and crystalline ionic compounds; or
- Infer that bonds are ionic or covalent.

## Chemical Bonding and Reactions

**PS-4 The student will demonstrate an understanding of chemical reactions and the classifications, structures, and properties of chemical compounds.**

**PS-4.5 Predict the ratio by which the representative elements combine to form binary ionic compounds, and represent that ratio in a chemical formula.**

**Taxonomy Level:** 2.5-B Understand Conceptual Knowledge

### Key Concepts:

Binary ionic compounds

Chemical formula

Balanced charge

**Previous/Future knowledge:** In the 7<sup>th</sup> grade students translated chemical symbols and the chemical formulas of common substances to show the component parts of the substances (including NaCl [table salt], H<sub>2</sub>O [water], C<sub>6</sub>H<sub>12</sub>O<sub>6</sub> [simple sugar], O<sub>2</sub> [oxygen gas], CO<sub>2</sub> [carbon dioxide], and N<sub>2</sub> [nitrogen gas]). (7-5.2) In Physical Science students will predict the ratio and write formulas for binary ionic compounds.

### It is essential for students to

- Predict the charge of the ions that the atoms in Groups 1, 2, 16, and 17 will attain.
  - Group 1 metals form 1+ ions,
  - Group 2 metals form 2+ ion,
  - Group 16 nonmetals form 2- ions,
  - Group 17 nonmetals form 1- ions.
- Understand that a *chemical formula* indicates the ratio of atoms in a molecule or an ionic compound.
  - The formula tells what elements are in the substance using symbols, and
  - The formula indicates the number of atoms of each element in a unit of the substance using subscripts.
- Understand the meaning of the symbols and subscripts when given a chemical formula.
- Understand that compounds do not have a net charge, meaning that the negative charges balance the positive charges so that the compound as a whole is neutral.
- Write balanced chemical formulas for binary ionic compounds.
  - Balance the charges in chemical formulas of compounds that contain ions of the elements in Groups 1,2,16, and, 17 without being given the charges on the ions
  - Balance the charges on *binary ionic compounds* (two different elements bonded together) for any elements that form ionic compounds when the charges on the ions are given, thereby predicting the ratio of the ions in the formula of the resulting ionic compound.

### It is not essential for the students to:

- Balance formulas for ionic compounds other than Group 1, 2, 16, and 17 unless charges are given;
- Understand percent ionic character.

## Chemical Bonding and Reactions

**PS-4 The student will demonstrate an understanding of chemical reactions and the classifications, structures, and properties of chemical compounds.**

### Assessment Guidelines:

The first objective of this indicator is to predict the ratio of ions in binary ionic compounds, therefore, the primary focus of assessment should be to infer from the charges for Groups 1,2,16, and 17 ions based on the periodic table the ratio between the two elements forming the ionic bond.

Another objective of this indicator is to represent this ratio of ions in the form of a chemical formula; therefore, the primary focus of assessment should be to write a balanced chemical formula.

In addition to predict, assessment may require students to

- Infer charges of Groups 1, 2, 16, and 17 ions;
- Recognize balanced ionic formulas; or
- Exemplify ions with 1+, 2+, 1-, or 2- charges.

## Chemical Bonding and Reactions

**PS-4 The student will demonstrate an understanding of chemical reactions and the classifications, structures, and properties of chemical compounds.**

**PS-4.6 Distinguish between chemical changes (including the formation of gas or reactivity with acids) and physical changes (including changes in size, shape, color, and/or phase).**

**Taxonomy Level:** 4.1 B Analyze Conceptual Knowledge

### Key Concepts:

Chemical change: gas formation, reaction with acids, tarnish

Physical change: phase change, expand/contract

**Previous/Future knowledge:** In the 7<sup>th</sup> grade students compared physical properties of matter (including melting or boiling point, density, and color) to the chemical property of reactivity with a certain substance (including the ability to burn or to rust) (7-5.9); and compared physical changes (including changes in size, shape, and state) to chemical changes that are the result of chemical reactions (including changes in color or temperature and formation of a precipitate or gas) (7-5.10). The 7<sup>th</sup> grade students were also introduced to acids (7-5.6).

In Physical Science the students will expand the concept for evidences of chemical changes that include the formation of a gas and reactivity with acids. They will expand their concept for evidences of physical changes to include changes in phase, size, shape, and color. Students will look at these evidences and determine the relevance of the evidence to distinguish changes that are physical from those that are chemical.

### It is essential for students to understand

#### *Chemical Changes*

- A chemical change occurs when there is a change in the arrangement of the atoms involved so a different substance with different properties is produced. When a chemical reaction takes place some type of evidence can be observed.
  - One type of evidence might the formation of a new gas. This gas is not a phase change but is a new molecule formed by a chemical reaction. An example of this type of reaction would be the reaction of baking soda with vinegar. Carbon dioxide gas is formed which is evidence that a chemical reaction has occurred. The atoms are rearranged and a new substance (carbon dioxide) is formed.
- The reaction of a substance with an acid is another chemical change
  - Active metals react with acids. The metal will replace the hydrogen in the acid and form a salt and hydrogen gas. The atoms are rearranged and new substances are formed with different properties so this is a chemical change.
  - Acids react with bases to form water and a salt (neutralization reaction). The atoms are rearranged and new substances are formed with different properties so this is a chemical change.
- Color change may be evidence that chemical change has occurred.
  - Metal tarnishing and changing color is a chemical change because in this case atoms are rearranged and a new substance is formed.
  - The tarnish is a compound formed when the metal and another substance (such as oxygen or sulfur) combine.

## Chemical Bonding and Reactions

**PS-4 The student will demonstrate an understanding of chemical reactions and the classifications, structures, and properties of chemical compounds.**

### ***Physical Changes***

- A *physical change* is a change in matter from one form or appearance to another but does not involve a change in the identity of a substance.
- When physical changes occur a new substance is not produced.
  - A substance may change size, such as being broken into smaller pieces,
  - A substance may change in shape, such as being bent or stretched,
  - A substance may expand or contract due to a temperature change.
- Color change may indicate a physical change.
  - When different colors of paint, crayon, or food coloring are mixed together a mixture is formed and the color changes. No rearrangement of the atoms occurs. You still have the same substances that you started with they are just mixed together. This is a physical change.
- Phase changes (freezing, melting, evaporation, sublimation, etc.) are physical changes.

**It is not essential for students to** write chemical equations to show that chemical changes (reactions) have occurred.

### **Assessment Guidelines:**

The objective of this indicator is to *distinguish* chemical changes, like gas formation or reactivity with acids, from physical changes, such as change in size, shape, color, or phase, therefore, the primary focus of assessment should be to differentiate among the criteria for physical change and chemical change. Assessments may require that students be able to determine the reason a change is chemical or physical.

In addition to *distinguish*, assessments may require that students

- *Classify* these changes as chemical or physical changes;
- *Exemplify* chemical and physical changes;
- *Infer* from a description of a change whether it is a chemical change or not;
- *Compare* physical and chemical changes.

## Chemical Bonding and Reactions

**PS-4 The student will demonstrate an understanding of chemical reactions and the classifications, structures, and properties of chemical compounds.**

**PS-4.7 Summarize characteristics of balanced chemical equations (including conservation of mass and changes in energy in the form of heat—that is, exothermic or endothermic reactions)**

**Taxonomy Level:** 2.4-B Understand Conceptual Knowledge

### Key Concepts:

Chemical equation: Balanced equation

Conservation of mass

Energy change : Exothermic, Endothermic

**Previous/Future knowledge:** Students in the 7<sup>th</sup> grade explained how a balanced chemical equation supports the law of conservation of matter (7-5.8). This is the first time students relate chemical equations to energy change occurring in a chemical reaction.

### It is essential for the student to

- Understand that a *chemical equation* uses chemical formulas and symbols to show the reactants and the products in a chemical reaction.
- Understand that a *balanced chemical equation* represents the process of a chemical reaction where atoms are rearranged but not created or destroyed.
  - The equation shows that the same atoms that existed before the chemical reaction (in the reactants) are still there after the reaction (in the products).
  - Mass is conserved; the law of conservation of mass states that the mass of all substances that are present before a chemical change equals the mass of all the substances that are remaining after a chemical change.
- Understand that there is always an energy change when a chemical reaction occurs.
  - If heat is given off it is called an *exothermic* reaction. This type of reaction releases heat to the area around the reaction, so this area will become warmer.
  - If heat is absorbed it is called an *endothermic* reaction. This type of reaction takes heat from the area surrounding it, so the area around the reaction will become cooler.

### If is not essential for the student to

- Predict whether a reaction will be endothermic or exothermic or give reasons why;
- Calculate heat released or absorbed.

### Assessment Guidelines:

The objective of this indicator is to summarize the concepts involved in balanced chemical equations including conservation of mass and endothermic or exothermic reactions, therefore, the primary focus of assessment should be to generalize major points about balanced equations in the context of conservation of mass and changes in energy.

In addition to *summarize*, assessments may require that students

- Compare endothermic and exothermic reactions;
- Infer that endothermic or exothermic reactions have occurred given evidence (such as the container the reaction occurs in becomes cold.);
- Exemplify characteristics of reactions.

## Chemical Bonding and Reactions

**PS-4 The student will demonstrate an understanding of chemical reactions and the classifications, structures, and properties of chemical compounds.**

**PS-4.8 Summarize evidence (including the evolution of gas; the formation of a precipitate; and/or changes in temperature, color, and/or odor) that a chemical reaction has occurred.**

**Taxonomy Level:** 2.4-B Understand Conceptual Knowledge

### Key Concepts:

Chemical reaction

Evidence of a reaction: evolution of a gas, precipitate, energy change

**Previous/Future knowledge:** Students in the 7<sup>th</sup> grade compared physical properties of matter (including melting or boiling point, density, and color) to the chemical property of reactivity with a certain substance (including the ability to burn or to rust) (7-5.9); and compared physical changes (including changes in size, shape, and state) to chemical changes that are the result of chemical reactions (including changes in color or temperature and formation of a precipitate or gas) (7-5.10). In Physical Science students will study the various evidences to verify that a chemical reaction takes place.

### It is essential for students to

Understand that when a chemical reaction occurs, there is some observable evidence, but evidence that a chemical reaction has occurred should be weighed carefully. Evidence is not proof. It is the combination of evidences that give validation for a chemical or physical change.

- When bubbles form, it may be evidence that a chemical reaction has occurred and that a new gas has been formed.
  - An example of this is adding an active metal such as zinc to a hydrochloric acid solution. Hydrogen gas will evolve. This is evidence that a chemical reaction has occurred.
  - Bubbles could also be evidence that boiling, which is a physical change, is occurring.
- When a *precipitate* forms, it could be evidence that an insoluble solid has formed and fallen out of solution. This is a chemical reaction.
  - An example of this is adding a solution of silver nitrate to a solution of sodium chloride, a white precipitate of silver chloride is formed.
  - It could also be true that some of a substance that was dissolved has fallen out of solution because of a change in conditions. This is a physical change.
- In all chemical reactions there is an energy change.
  - When paper burns, heat and light are given off, an exothermic change. This would be evidence that a chemical reaction has occurred.
  - Many physical changes also involve an energy change. For instance, melting is an endothermic change.
- Color change can be an evidence for a chemical change.
  - When iron rusts or when silver tarnishes, it changes color. This is a chemical change.
  - Color change can also be due to physical factors such as a change in the way light is shining on an object or the mixing of different colors of paint. This is not a chemical change.
- An odor being given off is often evidence that a chemical reaction has occurred.
  - When ammonium carbonate is heated the odor of ammonia gas can be detected. This is a chemical reaction.
  - Odor can also occur because molecules are evaporating from the surface of a substance, which is a physical change.

## Chemical Bonding and Reactions

**PS-4 The student will demonstrate an understanding of chemical reactions and the classifications, structures, and properties of chemical compounds.**

**It is not essential for the student to** provide the reasons for the exceptions to the evidence. (When a gas evolves, the student should reason that this is evidence, not proof, that a chemical reaction has occurred).

### **Assessment Guidelines:**

The objective of this indicator is to summarize the concepts involved in finding evidence of a chemical reaction, therefore, the primary focus of assessment is should be to generalize major points about evidences for chemical and physical changes.

In addition to *summarize*, assessments may require that students

- Infer that reactions occur when certain evidences are presented;
- Exemplify or illustrate chemical reactions;
- Recall evidences that may indicate a chemical reaction has occurred.

## Chemical Bonding and Reactions

**PS-4 The student will demonstrate an understanding of chemical reactions and the classifications, structures, and properties of chemical compounds.**

**PS-4.8 Summarize evidence (including the evolution of gas; the formation of a precipitate; and/or changes in temperature, color, and/or odor) that a chemical reaction has occurred.**

**Taxonomy Level:** 2.4-B Understand Conceptual Knowledge

### Key Concepts:

Chemical reaction

Evidence of a reaction: evolution of a gas, precipitate, energy change

**Previous/Future knowledge:** Students in the 7<sup>th</sup> grade compared physical properties of matter (including melting or boiling point, density, and color) to the chemical property of reactivity with a certain substance (including the ability to burn or to rust) (7-5.9); and compared physical changes (including changes in size, shape, and state) to chemical changes that are the result of chemical reactions (including changes in color or temperature and formation of a precipitate or gas) (7-5.10). In Physical Science students will study the various evidences to verify that a chemical reaction takes place.

### It is essential for students to

Understand that when a chemical reaction occurs, there is some observable evidence, but evidence that a chemical reaction has occurred should be weighed carefully. Evidence is not proof. It is the combination of evidences that give validation for a chemical or physical change.

- When bubbles form, it may be evidence that a chemical reaction has occurred and that a new gas has been formed.
  - An example of this is adding an active metal such as zinc to a hydrochloric acid solution. Hydrogen gas will evolve (given off as a product of the reaction). This is evidence that a chemical reaction has occurred.
  - Bubbles could also be evidence that boiling, which is a physical change, is occurring.
- When a *precipitate* forms, it could be evidence that an insoluble solid has formed and fallen out of solution. This is a chemical reaction.
  - An example of this is adding a solution of silver nitrate to a solution of sodium chloride, a white precipitate of silver chloride is formed.
  - It could also be true that some of a substance that was dissolved has fallen out of solution because of a change in conditions. This is a physical change.
- In all chemical reactions there is an energy change.
  - When paper burns, heat and light are given off, an exothermic change. This would be evidence that a chemical reaction has occurred.
  - Many physical changes also involve an energy change. For instance, melting is an endothermic change.
- Color change can be an evidence for a chemical change.
  - When iron rusts or when silver tarnishes, it changes color. This is a chemical change.
  - Color change can also be due to physical factors such as a change in the way light is shining on an object or the mixing of different colors of paint. This is not a chemical change.
- An odor being given off is often evidence that a chemical reaction has occurred.
  - When ammonium carbonate is heated the odor of ammonia gas can be detected. This is a chemical reaction.
  - Odor can also occur because molecules are evaporating from the surface of a substance, which is a physical change.

## Chemical Bonding and Reactions

**PS-4 The student will demonstrate an understanding of chemical reactions and the classifications, structures, and properties of chemical compounds.**

**It is not essential for the student to** provide the reasons for the exceptions to the evidence.

(When a gas evolves – is given off in the reaction, the student should reason that this is evidence, not proof, that a chemical reaction has occurred).

### **Assessment Guidelines:**

The objective of this indicator is to summarize the concepts involved in finding evidence of a chemical reaction, therefore, the primary focus of assessment is should be to generalize major points about evidences for chemical and physical changes.

In addition to *summarize*, assessments may require that students

- Infer that reactions occur when certain evidences are presented;
- Exemplify or illustrate chemical reactions;
- Recall evidences that may indicate a chemical reaction has occurred.

## Chemical Bonding and Reactions

**PS-4 The student will demonstrate an understanding of chemical reactions and the classifications, structures, and properties of chemical compounds.**

**PS-4.9 Apply a procedure to balance equations for a simple synthesis or decomposition reaction.**

**Taxonomy Level:** 3.2-C Apply Procedural Knowledge

### Key Concepts:

Formulas of substances: subscripts

Balanced equation: coefficients

Synthesis reaction equation

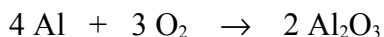
Decomposition reaction equation

**Previous/Future knowledge:** Students in the 7<sup>th</sup> grade “explained how a balanced chemical equation supports the law of conservation of matter.” (7-5.8)

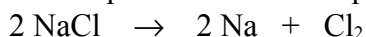
In Physical Science students will expand concept of balanced chemical equations. Students will write balanced formulas for some ionic compounds. Students will apply a procedure to manipulate coefficients to balance some chemical equations.

### It is essential for students to

- Understand that each substance has a formula showing its composition. It is essential to have the correct formula of each substance involved in a reaction before attempting to write a balanced equation.
  - Subscripts are part of the formula for a substance.
  - Subscripts indicate the number of atoms or ions in one chemical unit of that substance.
- Understand that a *balanced equation* represents a chemical reaction that rearranges atoms but does not create or destroy them.
  - For each element, the number of atoms on the reactant side must equal the number of atoms on the product side.
  - *Coefficients* indicate the number of units of each material that is involved in a reaction.
- Understand that subscripts are used to write the formula for a substance; the coefficient in front of the formula is then used to balance the equation after the formulas are written correctly.
- Manipulate only coefficients to balance the atoms in the equation for a simple *synthesis reaction* (two or more reactants combine to form one product) or *decomposition reaction* (a single reactant is broken apart into two or more products).
  - Example of a balanced synthesis reaction equation: (The coefficients are underlined in this example.)



- Example of a balanced decomposition reaction equation:



(If the coefficient is one, the number 1 is often not written down, such as  $\text{Cl}_2$ , and the coefficient is understood to be one.)

### It is not essential for students to

- Balance equations other than those for simple synthesis or decomposition reactions.

## Chemical Bonding and Reactions

**PS-4 The student will demonstrate an understanding of chemical reactions and the classifications, structures, and properties of chemical compounds.**

### Assessment Guidelines:

The objective of this indicator is to apply the procedure for balancing a synthesis or a decomposition chemical equation, therefore, the primary focus of assessment should be to know the procedure for balancing the equations and apply it to the situations of balancing simple synthesis and decomposition reactions.

In addition to *apply*, assessment may require students to

- Recognize balanced equations;
- Identify the number of each type of atom on each side;
- Recall that the number of each type of atom will remain the same;
- Exemplify synthesis and decomposition equations.

## Chemical Bonding and Reactions

**PS-4 The student will demonstrate an understanding of chemical reactions and the classifications, structures, and properties of chemical compounds.**

**PS-4.10 Recognize simple chemical equations (including single replacement and double replacement) as being balanced or not balanced.**

**Taxonomy Level:** 1.1-B Remember Conceptual Knowledge

### Key Concepts:

Single replacement reaction

Double replacement reaction

**Previous/Future knowledge:** Students in the 7<sup>th</sup> grade “explained how a balanced chemical equation supports the law of conservation of matter” (7-5.8).

In Physical Science students expand the concept of balanced chemical equations by recognizing when certain equations are balanced or not balanced.

### It is essential for students to know

- That a *single replacement* (displacement) reaction is a reaction in which one element takes the place of another element in a compound. For example:  
$$\text{Zn} + 2 \text{HCl} \rightarrow \text{ZnCl}_2 + \text{H}_2$$
- That a double replacement (ionic exchange) reaction is a reaction in which there is an apparent exchange of atoms or ions between two compounds. For example:  
$$\text{FeS} + 2 \text{HCl} \rightarrow \text{H}_2\text{S} + \text{FeCl}_2$$
- That a balanced equation represents a chemical reaction that rearranges atoms but does not create or destroy them. For each element, the number of atoms on the reactant side must equal the number of atoms on the product side.
- The meaning of the coefficients and subscripts with respect to how many atoms are represented.

**It is not essential for students to** balance single replacement or double replacement (ion exchange) reactions, only recognize that they are balanced.

### Assessment Guidelines:

The objective of this indicator is to recognize that chemical reactions are balanced, therefore, the primary focus of assessment should be to recall what makes an equation balanced and identify an equation as balanced or not balanced.

## Chemical Bonding and Reactions

**PS-4 The student will demonstrate an understanding of chemical reactions and the classifications, structures, and properties of chemical compounds.**

**PS-4.11 Explain the effects of temperature, concentration, surface area, and the presence of a catalyst on reaction rates.**

**Taxonomy Level:** 2.7-B Understand Conceptual Knowledge

### Key Concepts:

Reaction rate factors: temperature, concentration, surface area, catalyst

Particle collisions

**Previous/Future knowledge:** In the 7<sup>th</sup> grade students compared physical changes (including changes in size, shape, and state) to chemical changes that are the result of chemical reactions (including changes in color or temperature and formation of a precipitate or gas). (7-5.10)  
In Physical Science students will expand their concept of chemical reactions. For the first time students will explain factors that affect the rate of reaction. Students will explain the affect that changes in temperature, concentration, surface area, and the presence of a catalyst have on reaction rate.

### It is essential for students to

Understand that chemical reactions occur when the particles of the reactants collide with sufficient energy to react. Factors that affect reaction rate are as follows:

- **Temperature:** When the temperature increases, the rate of a chemical reaction increases.
  - The average kinetic energy of the molecules of reactants increases with increased temperatures and a greater number of the molecules will be moving faster.
  - Since more of the particles are moving faster and fewer of the particles are moving slowly, there will be more **total collisions** between particles and more collisions can a mean faster reaction rate.
  - More of the reactant particles will be moving faster and will, therefore, have enough energy to produce **successful collisions** and the reaction will proceed faster.
- **Concentration:** When reactants are more concentrated, the rate of a chemical reaction can increase.
  - When reactants are more concentrated, it means there are more particles per unit volume. Because there are more particles in a given volume, there is a greater chance that reactant particles will collide.
  - More collisions can mean a faster reaction rate.
- **Surface Area:** When the surface area of reactants increases, the reaction rate increases.
  - Only the particles at the surface of a sample of reactant can collide with particles of other reactants.
  - If the same mass of reactants is broken into smaller pieces, there is greater surface area. With many more particles on the surface, there is a greater chance for collisions to occur, and the chemical reaction will proceed faster.
- **Catalyst:** A *catalyst* is a substance that speeds up a reaction without being permanently changed itself. The presence of a catalyst will speed up a chemical reaction.
  - Catalysts can lower the amount of energy needed to start a reaction (activation energy).
  - Since the energy needed for successful collisions is less, there will be more successful collisions, and the chemical reaction will proceed faster.

## Chemical Bonding and Reactions

**PS-4 The student will demonstrate an understanding of chemical reactions and the classifications, structures, and properties of chemical compounds.**

### It is not essential for students to

- Understand why a catalyst lowers activation energy or define activation energy;
- Understand catalysts that work by a mechanism other than lowering the activation energy such as surface catalysts which affect orientation.

### Assessment Guidelines:

The objective of this indicator is to explain how certain factors affect reaction rate, therefore, the primary focus of assessment should be to construct cause and effect relationships that show how and why temperature, surface area, concentration, and presence of a catalyst affect the reaction rate.

In addition to *explain*, assessments may require that students

- Compare reaction rates under different conditions;
- Summarize the effects of changes in temperature, surface area, concentration and presence of a catalyst on reaction rates;
- Infer the effects of changes in temperature, surface area, concentration and presence of a catalyst on reaction rates;
- Recall or recognize factors that affect reaction rates.